SUN-SPOT VARIATION IN LATITUDE, 1861–1902.

EVERYONE who is acquainted with sun-spot statistics is familiar with the law known as "Spörer's law of sun-spot zones," which was derived after a laborious series of sun-spot observations made by Spörer himself. Previous to this indefatigable worker, Carrington made a series of most valuable observations between the years 1853 and 1861, and it was he who first directed attention to the fact that sun-spots had a general drift towards the equator during a sun-spot cycle. To use his own words, he stated that there was indicated "a great contraction of the limiting parallels between which spots were formed for two years previously to the minimum of 1856, and, soon after this epoch, the apparent commencement of two fresh belts of spots in high latitudes, north and south, which have in subsequent years shown a tendency to coalesce, and ultimately to contract, as before, to extinction."

Discussing these and his own observations, Spörer was led not only to corroborate the deductions made by Carrington, but to formulate more definitely a law of sun-spot circulation, which he stated as follows:—

"Un peu avant le minimum, il'n'y a de taches que près de l'equateur solaire, entre $+5°$ et $-5°$. A partir du minimum, les taches, qui avaient depuis longtemps déserté les hautes latitudes, s'y montrent brusquement vers $\pm 30°$. Puis elles se multiplient, un peu partout, a peu près entre ces limites, jusqu'au maximum, mais leur latitude moyenne diminue constamment jusqu'à l'époque du nouveau minimum."

To arrive at this result Spörer made a very complete investigation of the position of every sun-spot that had been observed up to that time in relation to the solar equator. In fact, he brought together all the statistics of the latitudes of sun-spots for each hemisphere, and determined for each period of the sun's rotation the mean heliographic latitude of the spotted area. To indicate the variation from year to year of this mean heliographic latitude he published curves, and the special feature of these was that each commenced in high latitudes about the time of sun-spot minimum, and gradually approached the equator until the epoch of the following minimum, when a new cycle commenced in high latitudes, the two curves overlapping for a short time about the time of sun-spot minimum.

If Spörer's curves be closely examined it will be found that those which pass strictly through the actual points given by observation are of a *wavy* nature, and are sometimes above and below the mean curve from which Spörer deduced his law. In fact, Spörer himself directed attention to this peculiarity, and distinctly remarked on the subsidiary increases of spotted area and a reversion of spots to higher latitudes at times other than at sun-spot minimum. In later times Dr. Braun, of the Kalósca Observatory, pointed out similar anomalies from his own observations made between 1880 and 1884.

From the illustration (Fig. 2) accompanying this article curves B indicate the wavy nature of these mean heliographic curves, and it will be noticed that even up to the present time this peculiarity is a marked feature.

It was with the object of attempting to trace the origin of these variations—variations which indicated that Spörer's law might be only of a very general nature—that a recent investigation was commenced, the results of which were communicated to the Royal Society (February 11).

The method of analysis was to divide the limited region on the sun's surface in which spots appear into strips or zones, in a similar way to that employed in the study of the prominences (NATURE, vol. lxvii. p. 570). As solar prominences appear on any part of the disc, it was sufficient, in order to trace their distribution throughout a year, to divide the sun's surface into nine zones of 10 degrees each. Since, however, spots seldom occur above latitude 40°, the width of the zones had to be considerably diminished. For the present inquiry, it was decided to group the spots into belts 3 degrees wide, for even zones of 5 degrees in width were found to mask many important characteristics.

The necessity for such narrow zones will be seen from the accompanying figure (Fig. 1), in which the yearly distribution of spots is shown for the years 1879–1883, taking zones of 10 degrees, 5 degrees, and 3 degrees in width respectively.

In these curves each broad vertical line corresponds to the solar equator, and the scales to the right and left of each represent the north and south latitudes respectively. The heights of the curves above each horizontal zero line indicate the different amounts of spotted area, and the scales of these are so arranged that the curves are all proportional to the spotted area.

The curves themselves are formed by determining the mean spotted area for each zone, and plotting each value at the point representing the mean latitude of this zone; these points are then all joined together. Thus, in the case of the 0–10° zone, the mean spotted area is plotted at 5°, 10–20° at 15°, &c. The other zone divisions are similarly treated; thus 0–5° is plotted at 2·5°, 0–3° at 1·5°, &c.

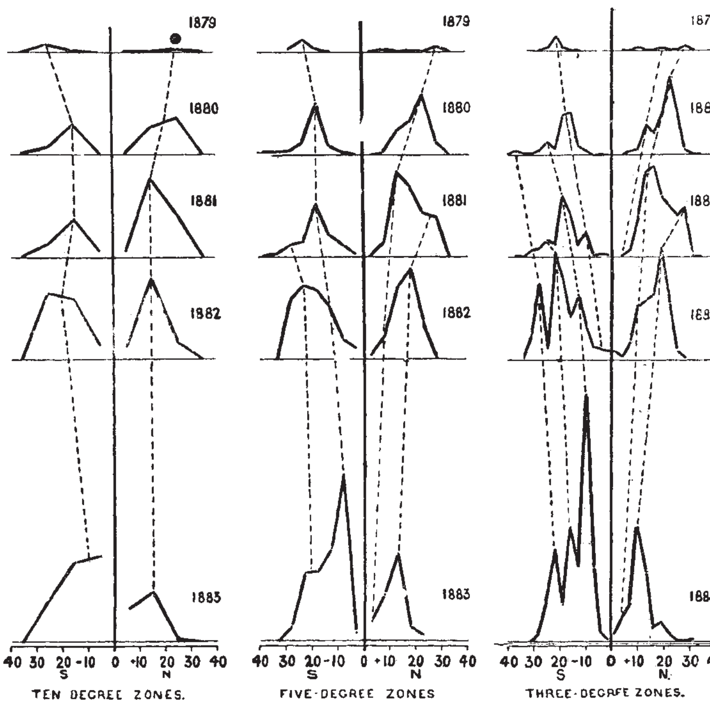

FIG. 1.—Distribution of Sun's Spotted Area.

In the 10° zone curves here shown there is only one maximum in each hemisphere for the years in question, and these, as indicated by the dotted curves which join them, do not progress gradually towards the equator as would probably be the case according to Spörer's law. With 5° zones it is possible to detect the presence of two maxima in one or other of the hemispheres, all of which have a trend towards the equator in succeeding years. Still more detail is displayed in the 3° zones, and here is apparent a spot distribution and movement which is practically masked in the two preceding sets of curves.

The advisability of adopting 3° zones being thus apparent the whole series of observations from the year 1861–1902 was treated in the above manner, the points plotted, and

the curves drawn as shown in the figure previously referred to.

In this way it was possible to trace the varying positions, as regards changes of latitude, of the centres of action, or maxima points of the curves, from year to year, just as was previously attempted in the case of the prominences. These centres of action were then connected by lines passing from one yearly curve to the next. It is worthy of remark that very little difficulty was met with in deciding the maxima points to be joined. There was always, throughout the whole period, a most distinct march of these points individually towards the equator, and the method of placing the curves one beneath the other rendered such movement at once obvious to the eye.

The diagram (Fig. 1) not only exhibits some of the types of curves met with, but shows how the various centres of maximum spot-activity were joined up with each other, year by year, for the period of time over which the curves extend, namely, from 1879, the year following a sun-spot minimum, to about a sun-spot maximum in 1883.

Considering the curves relating to the sun's northern hemisphere, it will be seen that in 1879, the year following a sun-spot minimum, when the spots were ending a cycle near the equator, two new outbreaks occurred in latitudes about 20° and 30°. These two centres of activity moved towards the equator next year, and by 1881 the former had disappeared, while the other rapidly grew in intensity and reached latitude 15°. During this year a new outbreak in latitude 30° made its appearance, and this in the two following years had an equatorial trend. A somewhat similar occurrence took place in the southern hemisphere, each of the centres of action moving rapidly towards the equator.

It is interesting to note the rapid growth and decay of these centres of action, an example of which is shown commencing in 1879 in latitude 28° in the northern hemisphere. Attention may particularly be directed to the three prominent maxima of the curves for the southern hemisphere in the years 1882 and 1883, which indicate that at this period there were three definite centres of spot action in existence.

To bring the results of the above analysis for the whole period of time investigated within a small compass the same method was adopted as that employed in the case of the prominence reduction to which reference has already been made.

In Fig. 2 the two sets of curves marked A indicate for each hemisphere the changes in the positions of these centres of spot-activity from year to year, plotted at equal intervals of a year. The striped portion is deduced from Spörer's observations, and the remainder from the Greenwich reductions. These lines have been proportionally thickened to indicate approximately the relative amount of spotted area at these centres of action, or, in other words, the heights of the maxima points on the yearly curves. These curves thus indicate for each year the positions, as regards latitude, of the centres of spot activity, and give an idea of the movements of these centres during each sun-spot cycle.

As these curves have here been called "spot-activity tracks," so "prominence-activity tracks" may be employed to indicate the equivalent variations as regards the prominences.

For the sake of comparison, curves B, C, and D have been added. Curves B show the variations of the mean heliographic latitude of the total spotted area for each hemisphere. Curves C illustrate the distribution and changes of position of the centres of prominence activity, or "prominence-activity tracks" as they may now be called. The small circles in the years 1870–1871 represent Respighi's observations, the curves from 1872–1881 those of Secchi and Tacchini, and the remainder, up to the year 1902, Ricco and Mascari's observations. The dotted curves previous to 1870 are intended

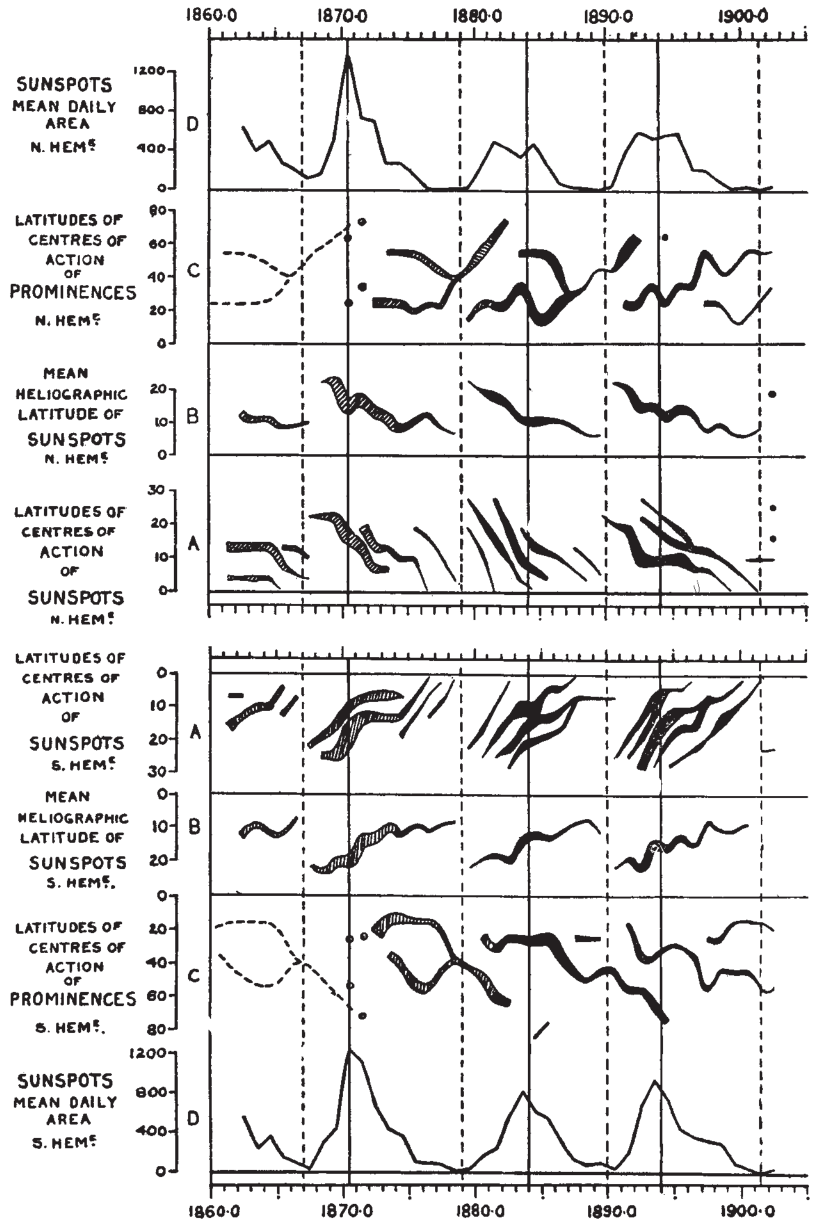

FIG. 2.—A comparison of the curves illustrating (A) spot-activity tracks; (B) mean heliographic latitude of sun-spots; (C) prominence-activity tracks; (D) variation of spotted area. (The continuous and broken vertical lines indicate the epochs of sun-spot maxima and minima respectively, the two hemispheres being taken together.)

only to give a rough idea of the prominence variations based on a repetition of the observations of 1872–1885. The last curves, namely, those marked D, represent the variation from year to year of the total spotted area on each hemisphere of the sun. The vertical broken and continuous lines indicate the epochs of sun-spot minima and maxima as determined by combining the amount of spotted area on both hemispheres of the sun.

Considering now the curves marked A, the following *general* deductions may be made :—

From sun-spot minimum to minimum there are three, but generally four, distinct "spot-activity tracks," or loci of movements of the centres of action of spot disturbance.

The first appearance of each of these "spot-activity tracks" occurs generally between a sun-spot minimum and the following maximum. After about the epoch of maximum no new "spot-activity tracks" of large magnitude are generally commenced.

Their first appearance is mostly in higher latitudes than 20° in each hemisphere.

They are faintly indicated at first, become more prominent and distinct, and finally thin out and fade away.

They all fade away in regions close to the equator.

There seems to be a tendency for each successive "spot-activity track" to make its appearance in latitudes higher than the one preceding it.

At, or a little after, the time of sun-spot maximum there is also a tendency for each "spot-activity track" to retain its latitude for a short time.

It is interesting now to examine these curves (A) in relation to those marked B, which, as previously pointed out, represent the drift from year to year of the mean heliographic spot latitude and illustrate Spörer's "law of zones." These latter (curves B) are individually really nothing more than the *integration* of the corresponding curves A. Every change of curvature in curves B is due to either the outburst of spots in another "spot-activity track" or to one "spot-activity track" becoming more intensified in relation to another, or, lastly, to the extinction of a "spot-activity track" as the equator has been reached, as shown in the curves A.

To illustrate this, let the curve for the mean heliographic spot latitude in the southern hemisphere (curves B) beginning in the year 1879 be considered. This is practically the period referred to above by Dr. Braun.

At this time there is only one "spot-activity track" (latitude 22°) in existence, as shown in curve A, so curve B consequently commences in the same latitude. By the next year the "spot-activity track" (curves A) has reached latitude 17°, and a new one has made its appearance in latitude 25°. Curve B, therefore, takes the mean position of about 20° when allowance has been made for the difference of intensity of these two tracks.

In the following year, 1881, both these "spot-activity tracks" have approached nearer the equator, but another has appeared in latitude 25°, so that the mean latitude for the whole hemisphere has only slightly changed.

By the year 1882 still another "spot-activity track" has come into existence in latitude 28°, while the first "spot-activity track" mentioned above has vanished. The mean latitude for the whole hemisphere, as is indicated in curve B for this epoch, is increased to latitude 20°. After this all three "spot-activity tracks" approach the equator, and curve B does the same, but owing to the relative changes in the amount of the spotted area in each of these "spot-activity tracks," as indicated by their thickness, the mean heliographic latitude curve suffers another change of curvature in 1885. In a similar way the various changes of curvature in all the other curves (curves B) can be accounted for.

Particular attention has been directed above to the fact that about the times of sun-spot maxima there is considerable spot-activity in the highest spot latitudes, which according to Spörer's law would not be expected. If reference be made to the sun-spot observations of Messrs. De La Rue, Stewart, Lœwy, and also to those by the Wilna observers, it will be seen that as early as 1872 it was pointed out, as an unlooked for fact, that at the sun-spot maximum of 1871 numerous spots appeared in high (spot) latitudes.

Finally, if a comparison be made between the curves A and C it will be seen that from the time of a sun-spot minimum, when the "prominence-activity tracks" are approaching more rapidly high latitudes, up to about a sun-spot maximum, when they reach their highest positions, nearly all the "spot-activity tracks" come into existence. Further, the nearer the "prominence-activity tracks" approach the poles the higher in latitude do these "spot-activity tracks" make their appearance, and this is the case for each hemisphere of the sun separately.

What the actual connection between these two different systems of currents is, it is not possible yet to say, but these facts suggest a close relationship.

The result of the present investigation thus leads to the following conclusions :—

(1) Spörer's law of spot zones is only approximately true, and gives only a very general idea of sun-spot circulation.

(2) Spörer's curves are the *integrated* result of two, three, and sometimes four "spot-activity track" curves, each of the latter falling nearly continuously in latitude.

(3) Spörer's and many other previous reductions have indicated the peculiar "wavy" nature of the integrated curve, which peculiarity is here shown to be for the most part real and not due to errors of observation, &c.

(4) Outbursts of spots in high latitudes are not restricted simply to the epochs at or about a sun-spot minimum, but occur even up to the time of sun-spot maximum.

(5) The successive commencement of the "spot-activity tracks" in higher latitudes between a sun-spot minimum and maximum seems to be closely related to the "prominence-activity tracks" at these periods.

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THE DUNEDIN MEETING OF THE AUSTRALASIAN ASSOCIATION.

THE tenth session of the Australasian Association for the Advancement of Science was opened at Dunedin, New Zealand, on January 6, under the patronage of His Excellency the Earl of Ranfurly, the Governor of New Zealand, who took the chair at the inaugural meeting in the absence of the past president, Captain F. W. Hutton, F.R.S., whom ill-health prevented from attending.

The president, Prof. T. W. E. David, F.R.S., of Sydney, took as the subject of his address, "The Aims and Ideals of Australasian Science." Although this was wholly local in immediate interest, it was an extremely valuable epitome of the work already done by Australasian men of science. He dwelt upon the value of organisation in scientific research, and of the investigations carried out by research committees appointed at the meetings of the Australasian Association for the Advancement of Science. He applauded the good work done by the New Zealand Government in the preservation of the fauna and flora of New Zealand by the establishment of reserves, as well as in the establishment of a magnetic observatory at Christchurch, and urged the Commonwealth and State Governments of Australia to follow this lead.

In discussing the "Aims and Ideals," Prof. David, amongst other matters, referred to the proposed establishment in New South Wales of a branch of the Lick Observatory, to the importance of investigating the nature of the aurora australis, of carrying out a geodetic survey of Australia, and of continuing to support the high-level meteorological stations on Mt. Koscuisko. He insisted on the crying need for a systematic geological survey of New Zealand, and for the identification by competent palæontologists of the numerous fossils now stored in the Colonial Museum at Wellington, where there are "30,000 specimens in the museum cases, most of which are unnamed, and in the cellars about 500 unopened boxes full of undescribed fossils."

The president is of opinion that "nowhere in the southern hemisphere is there such a thorough and complete record of the succession of animal and plant life from the close of the Palæozoic time up to the present as in New Zealand, and nowhere else is there evidence of such a wonderful range of the Spiriferidæ high up in the Mesozoic rocks."

That important line of work in modern geology, viz. "the